# Fermilab Beam Test 2021: Preliminary results

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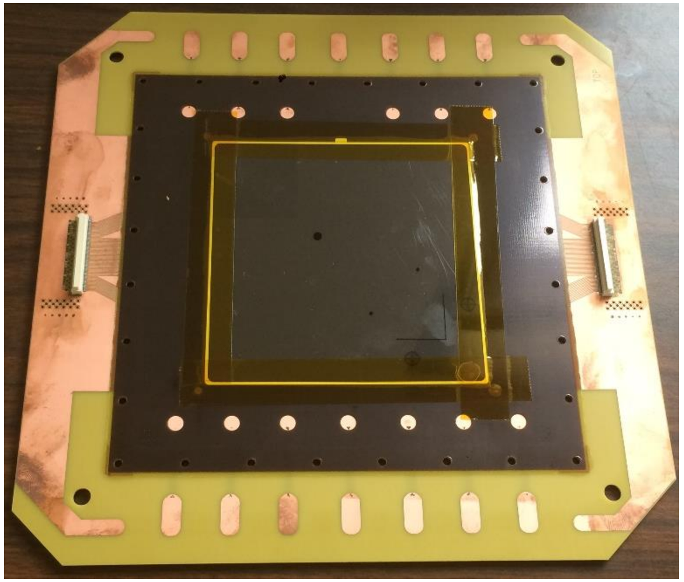
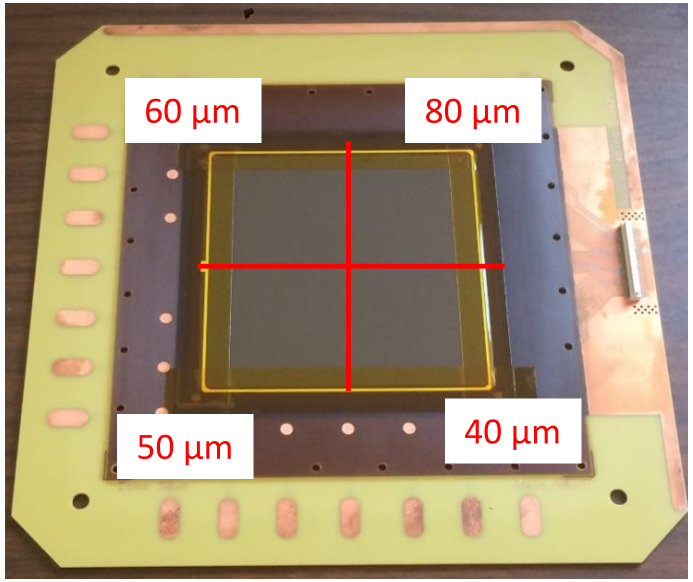
**EIC Weekly Meeting, July 26, 2021**

# GEM Protos with 5-layers Capacitive Sharing Pad Readout

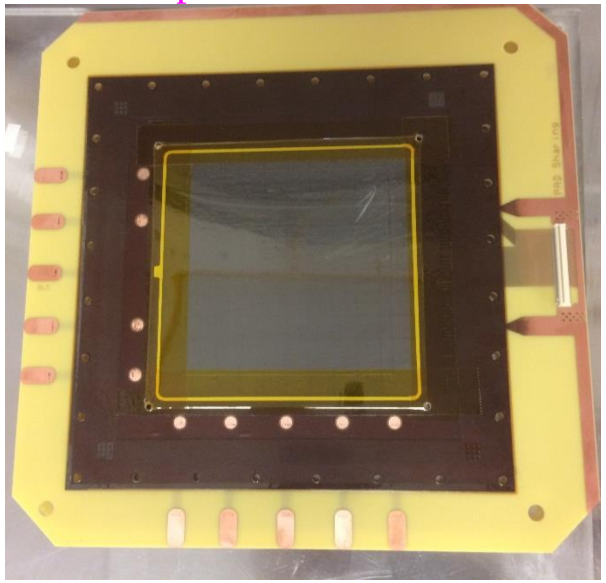
top pad: 0.4 mm × 0.4 mm
r/o pad: 6.4 mm × 6.4 mm



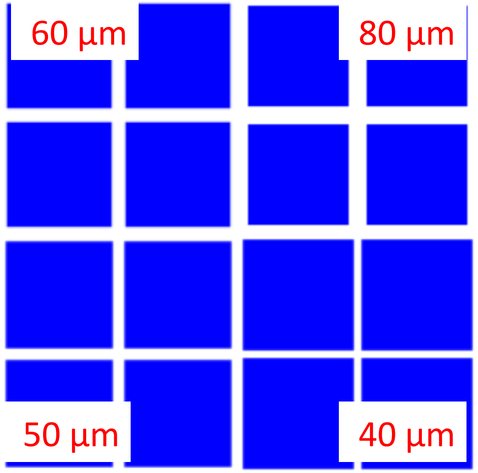
top pad: 0.5625 mm × 0.5625 mm
r/o pad: 9 mm × 9 mm

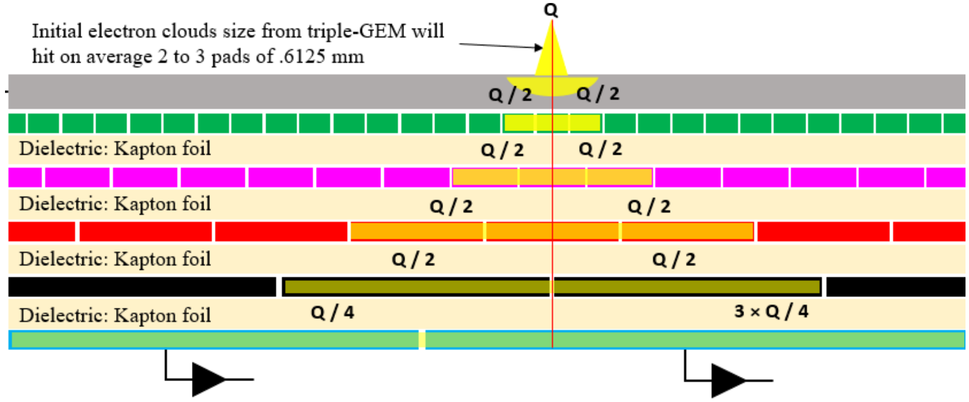



top pad: 0.625 mm×0.625 mm
r/o pad: 10 mm × 10 mm



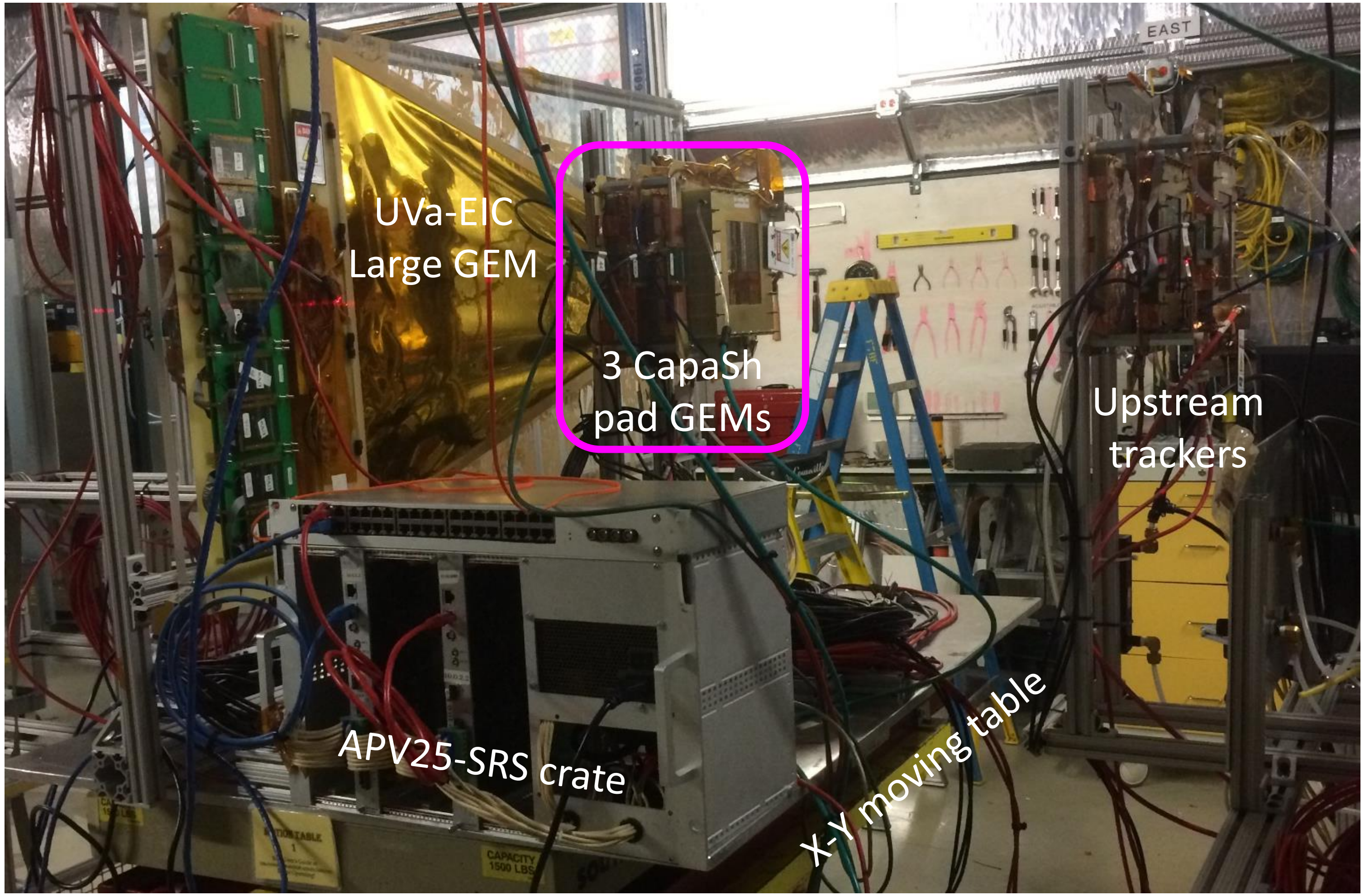
- All 3 r/o board: 5-pad layer capacitive-sharing scheme but different pitch for top and readout pad
  - Study of pad size on the resolution performance
- 9mm x 9mm r/o: area divided in 4 quadrants
  - For each quadrants: different inter pad gap
  - Same gap for 5 the pad layers in each quadrant, i.e variation between quadrants
  - Study impact of inter pad gap on resolution
- Position scan with 120 GeV proton to study resolution

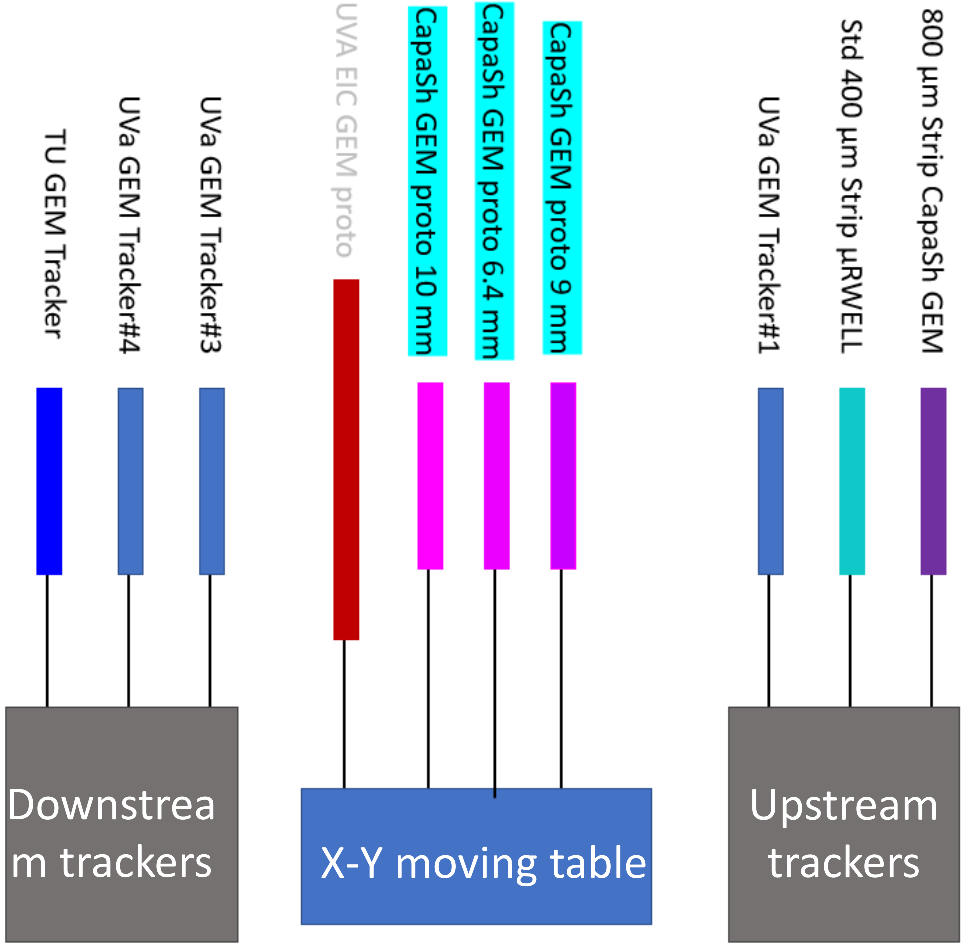


# Setup 1 @ FTBF MT62.b: GEMs with Capacitive Sharing Pad Readout

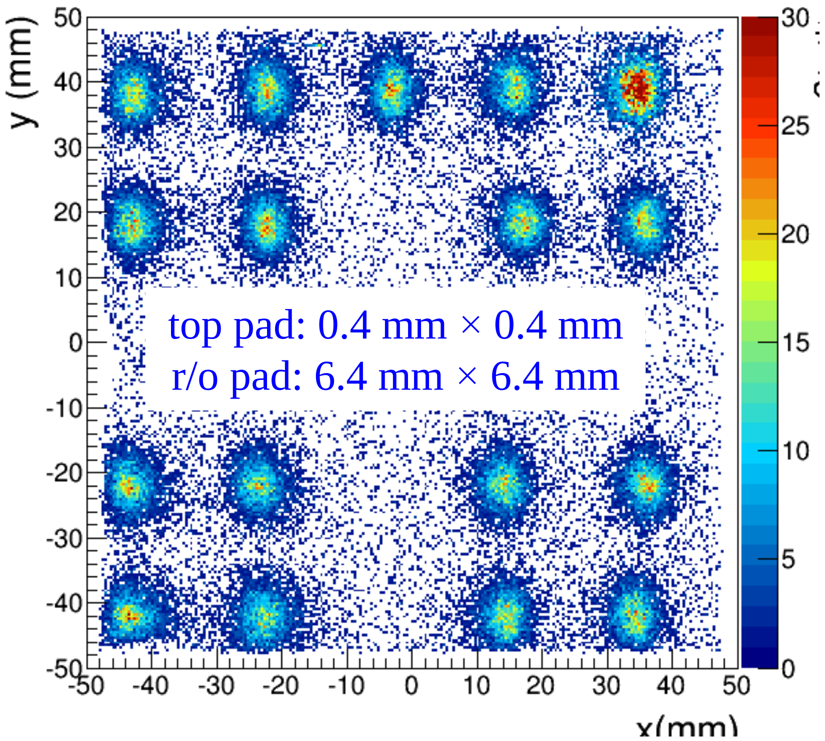
- 6 trackers including 4 COMPASS 10 × 10 triple GEMs and one UVa µRWELL with 400 um pitch X-Y R/O & one 800 µm X-Y capaSh GEM
- Large U-V strip EIC GEM prototype was not used (not powered …)
- Position scan and HV scan run for the 3 CapaSh pad readout GEMs with 120 GeV proton beams

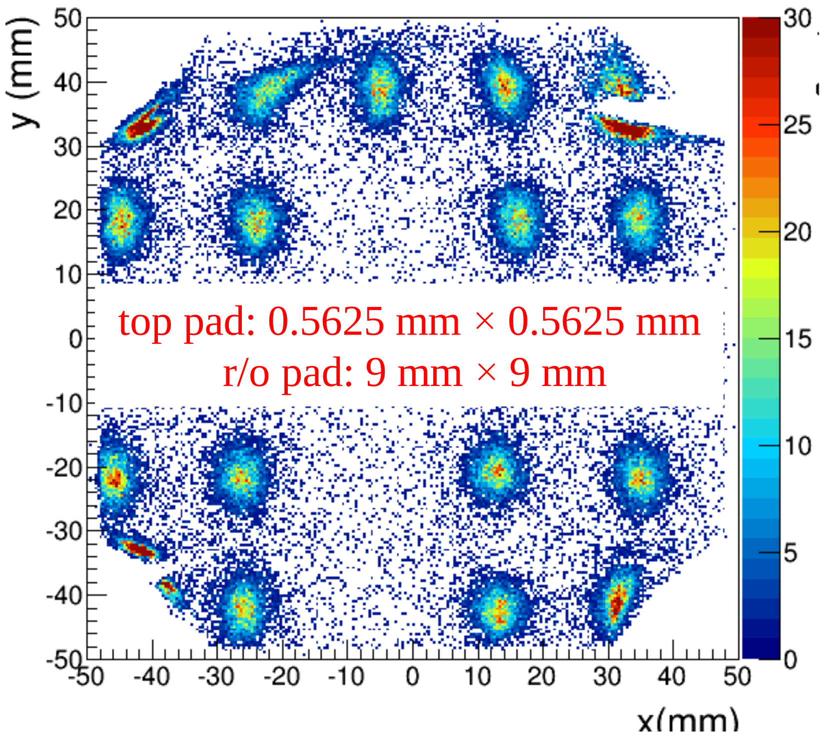


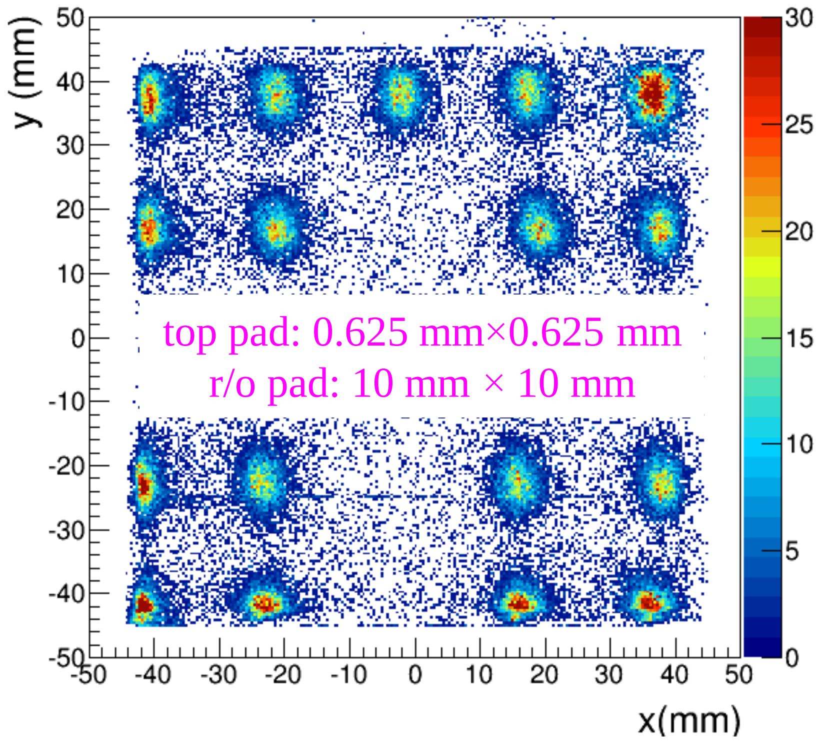



# Hit map from 12 GeV proton : Pad RO GEMs with Capacitive Sharing

- Preliminary hit map plots all 3 CapaSh pad readout GEMs from one position scan with a subset (~20%) of events of the run analyzed
- “Corner” effect on 9 mm capaSh pad readout prototype is because:
    - 12 × 12 pads => 144 channels => 4 pads in each corners un-connected to fit all channels in one single 128-ch Panasonic connector
- “Edge” distortion on 10 mm  capaSh pad readout prototype is because of Pad layer design at the edge of the readout of the first prototype
    - Edges effect not observed (or strongly reduced) for the 6.4 mm proto because both of smaller pad size but also
    - design has been modified on the subsequent prototypes



# GEM protos with Capacitive & Resistive Sharing X-Y Strip Readout

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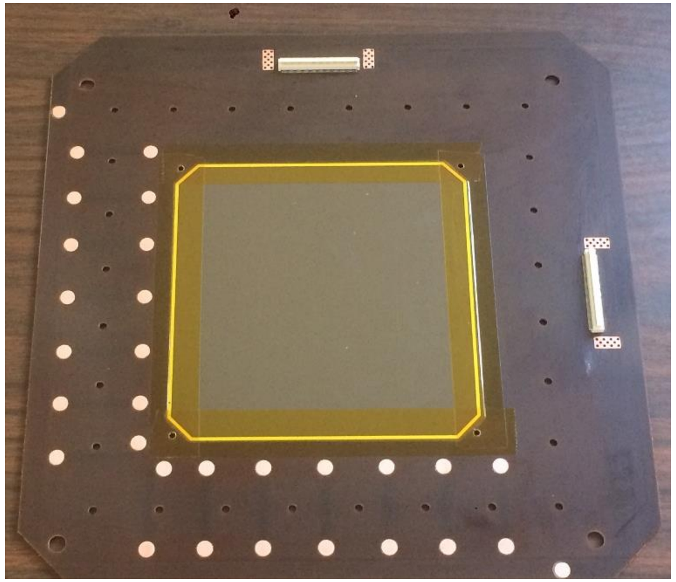
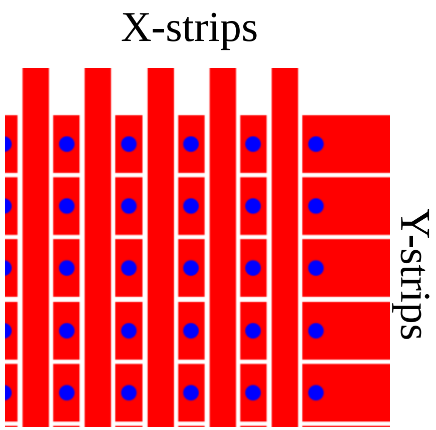
- Two GEM prototypes with **800 µm X-Y strip readout** tested at FNAL beam test
- Resistive sharing proto:
  - Charge spread through resistive layer DLC on top of the X-Y strip readout layer.
- Capacitive sharing proto:
  - Two pads layers (400 µm and 800 µm pad size) layers on top of the X-Y strip readout layer to help spread the charges
  - Also DLC layer on top of the 400 µm pad layer to help evacuate the GEM amplification charges to the ground
  - The DLC layer also of course participate to charge spreading, **but is not needed not even wanted other than to dissipate the charges to the ground**
- X-Y strip design identical for 2 prototypes
  - X-strip & Y-pad-like strip
  - One to one unbiased comparison of performances

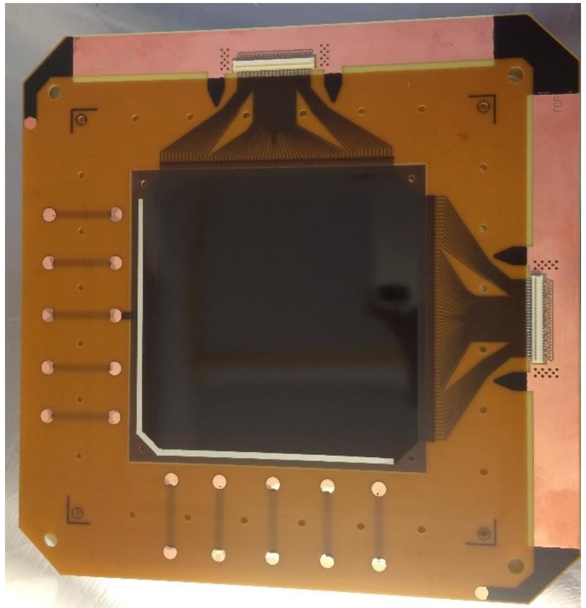
Capa-Sharing GEM proto

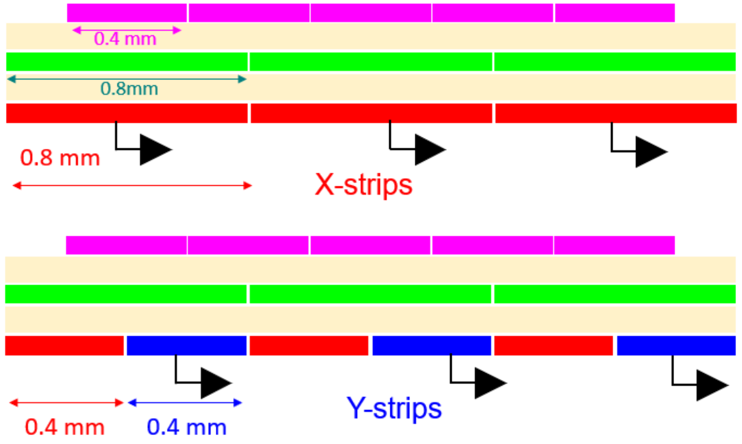


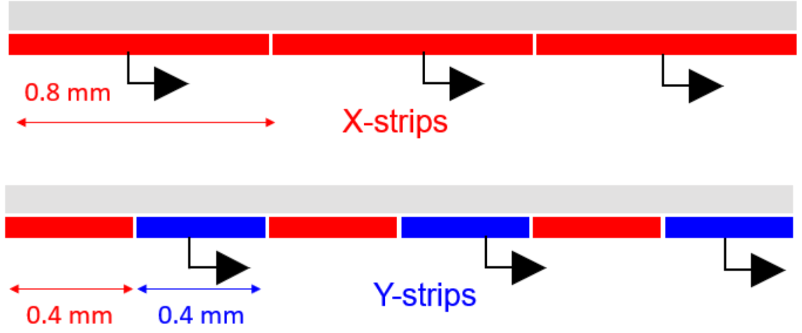
Gerber view of the X-Y strip readout design



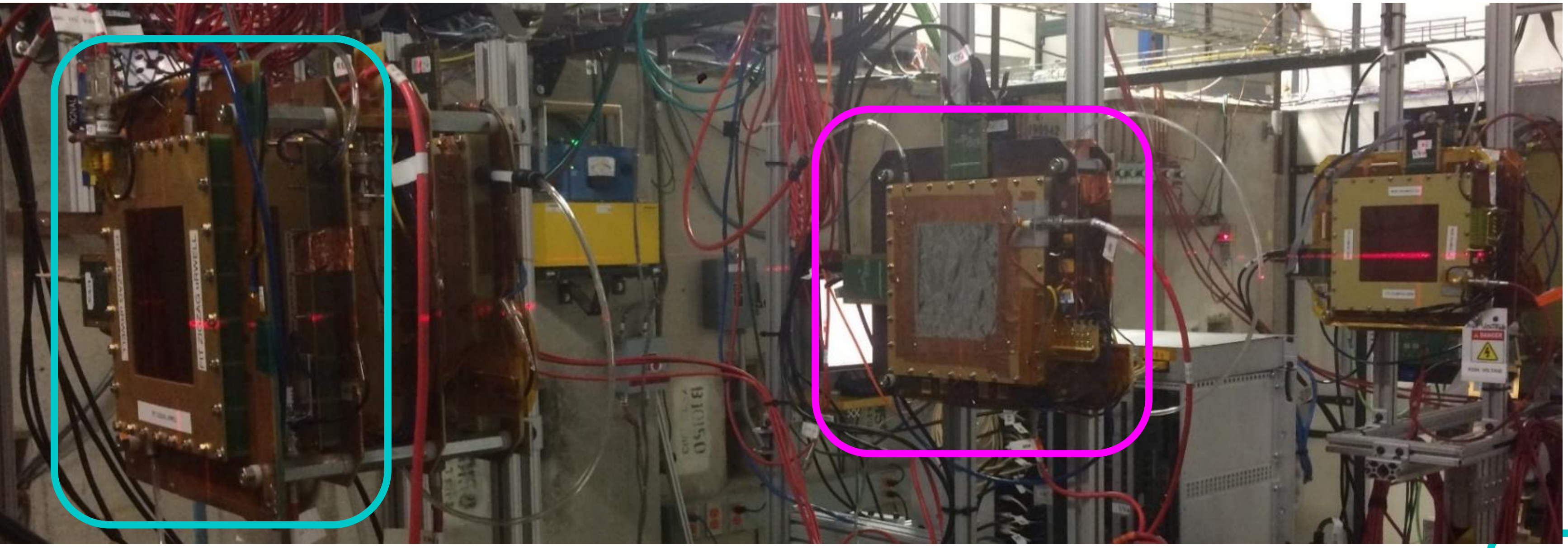

Res-sharing GEM proto





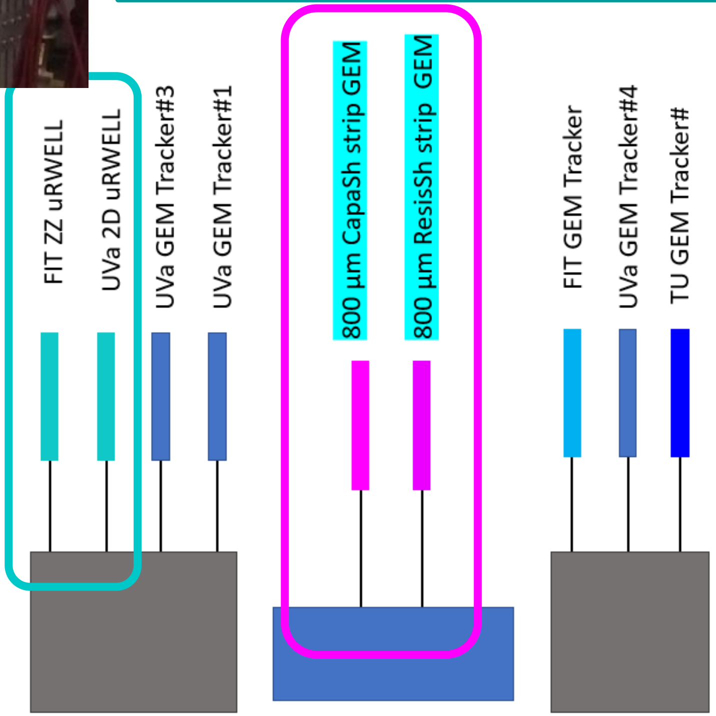



# Setup 2 @ FTBF MT62.b: GEMs with Capacitive & Resistive X-Y strip R/O



**Setup of 2 μRWELL protos**

- UVa proto with standard X-Y strip readout (400 μm)
- Florida Tech proto with 1D radial zigzag readout structure (R&D for EIC)
- uRWELL HV scan and drift HV scan




**Capacitive & resistive sharing X-Y strips GEM protos setup**

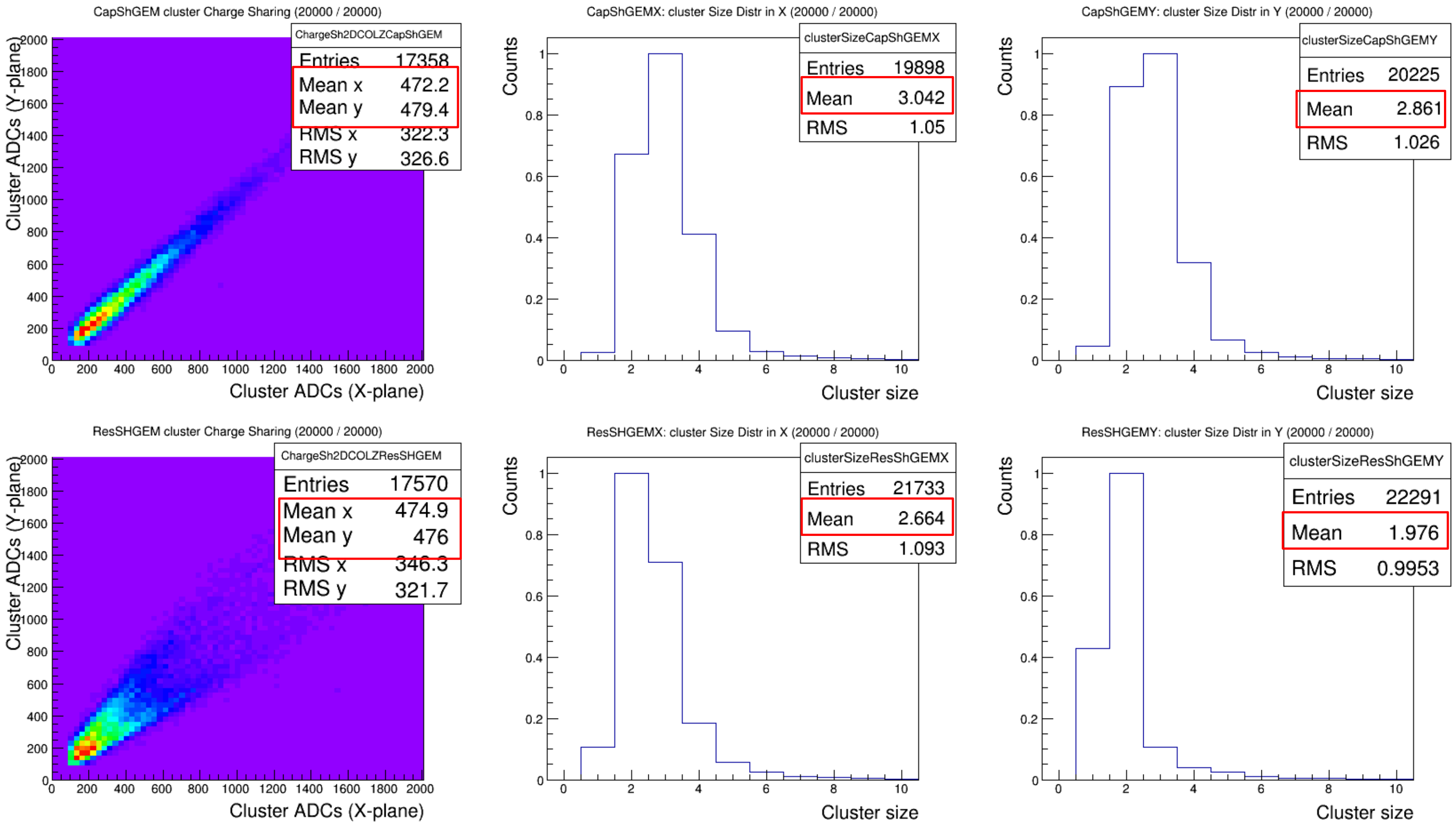
- 120 GeV proton beams @ 50k particles per 4s spill
- μRWELL prototype was not operational for the beam test period
    - Only GEM technologies with capacitive sharing strip readout
- DAQ trigger rate limited to 400Hz (just a fraction of the beam spill)
- HV scan & position scan runs
- GEM trackers upstream and downstream for spatial resolution analysis

# Performances of Capa and Resistive sharing GEMs with 12 GeV proton

- Very good X-Y charge sharing correlation and cluster size (> 3 strips in both X and Y) for capacitive sharing GEM prototype
- Correlation plot for X-Y charge sharing not very good => two slopes might indicate a non uniform performances across the active area
- Cluster size is also unequal between X and Y strips

Capacitive sharing GEM

Resistive sharing GEM

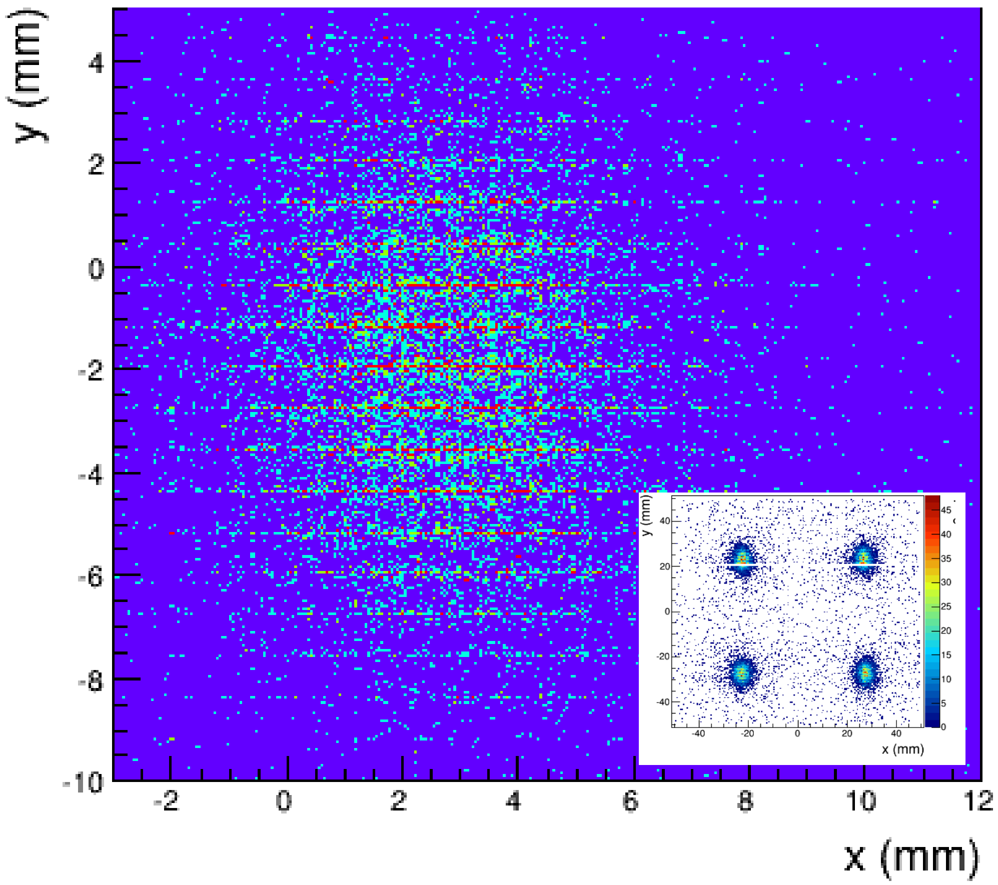



- These are very preliminary results => Needs more detailed analysis to untangle all the effects
- Comparison between two runs where Gain is similar in the Capacitive sharing and the resistive sharing protos

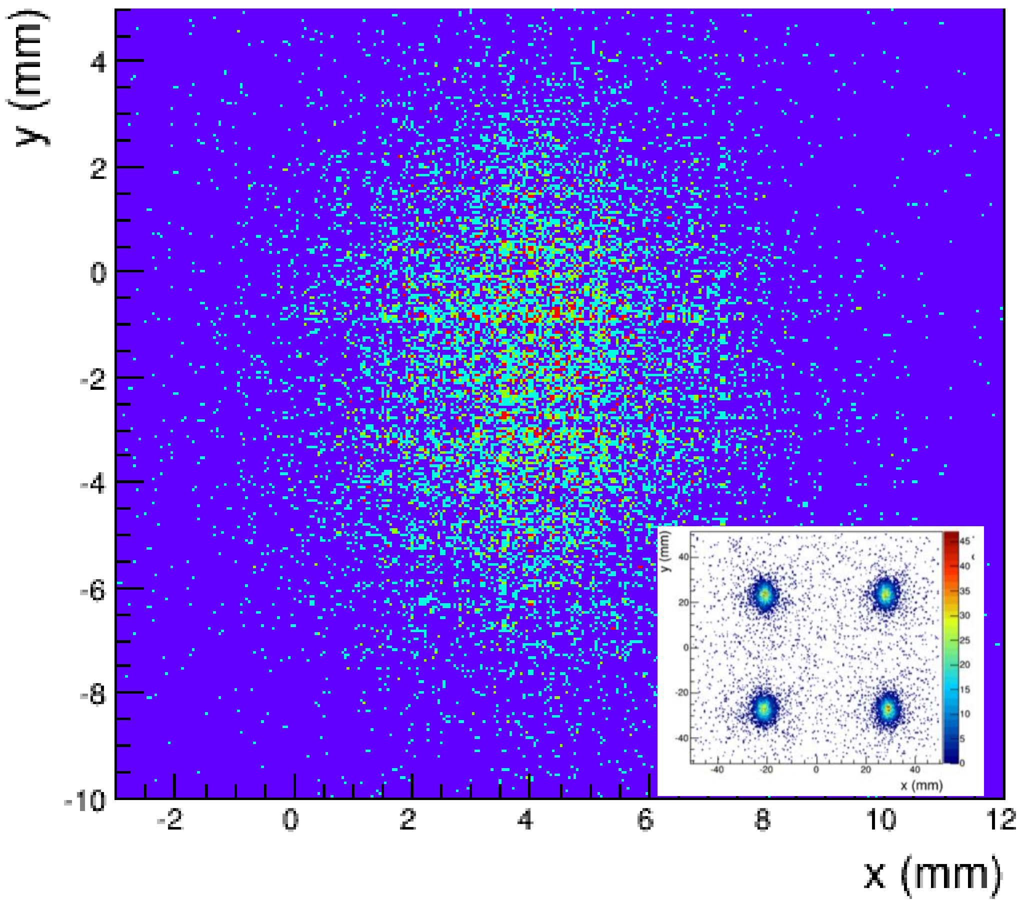
# Performances of Capa and Resistive sharing GEMs with 12 GeV proton

- A zoom on the hit map of the reconstructed beam spot shows  large distortion on the reconstructed hit position for the resistive sharing prototype more specially in the y-direction where the cluster size was small
- These distortions are far less prevalent for the capacitive-sharing prototype =>

Resistive sharing GEM




Capacitive sharing GEM



# Large & low mass GEM prototype with U-V strip readout

## Main goals / challenges of the current R&D:

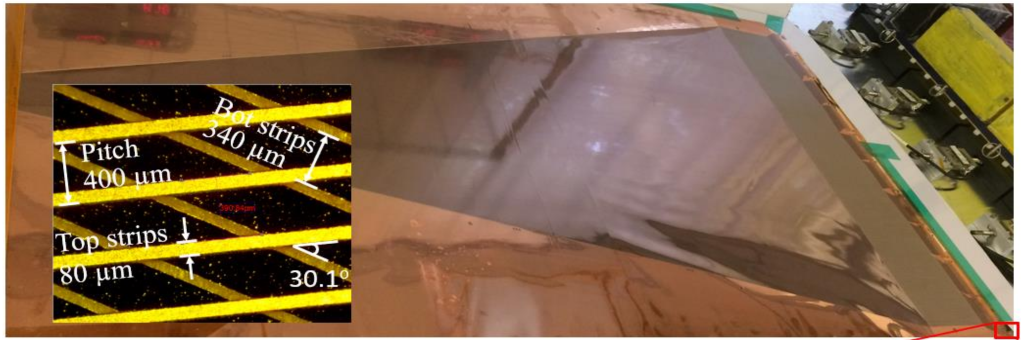
⇨ **Low Mass Detector:** All foils in the active area

- Drift Cathode & U-V strips readout foil are all foils
- No PCB or honeycomb in active area (300 μm spacer grids)
- Entrance and exit gas window ⇨ uniform gap b/w layers
- **0.45% r.l.**

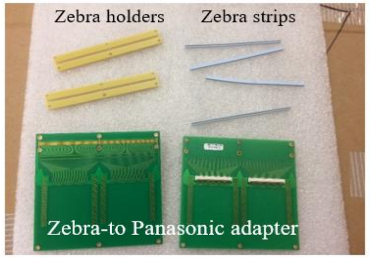
⇨ **Double sided zebra connection scheme:**

- Double the density of electronic channels in the outer radius
- **No FE cards on the back or the side of the detector**
- No vias necessary on the readout strip foil
    - **thin Cu layer (5 μm) for both U and V strips**

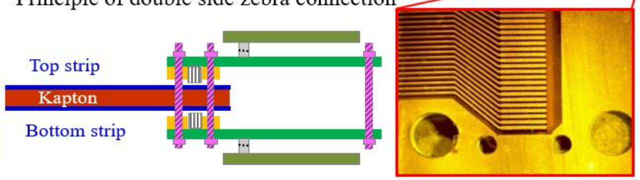
### U-V strip readout with double side zebra connection




Components of zebra connection

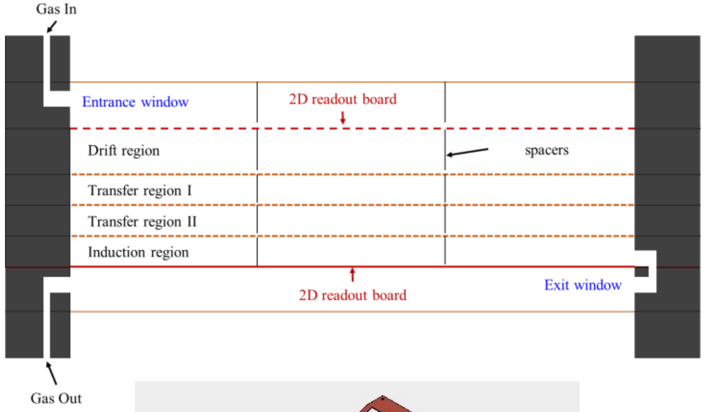



Principle of double side zebra connection

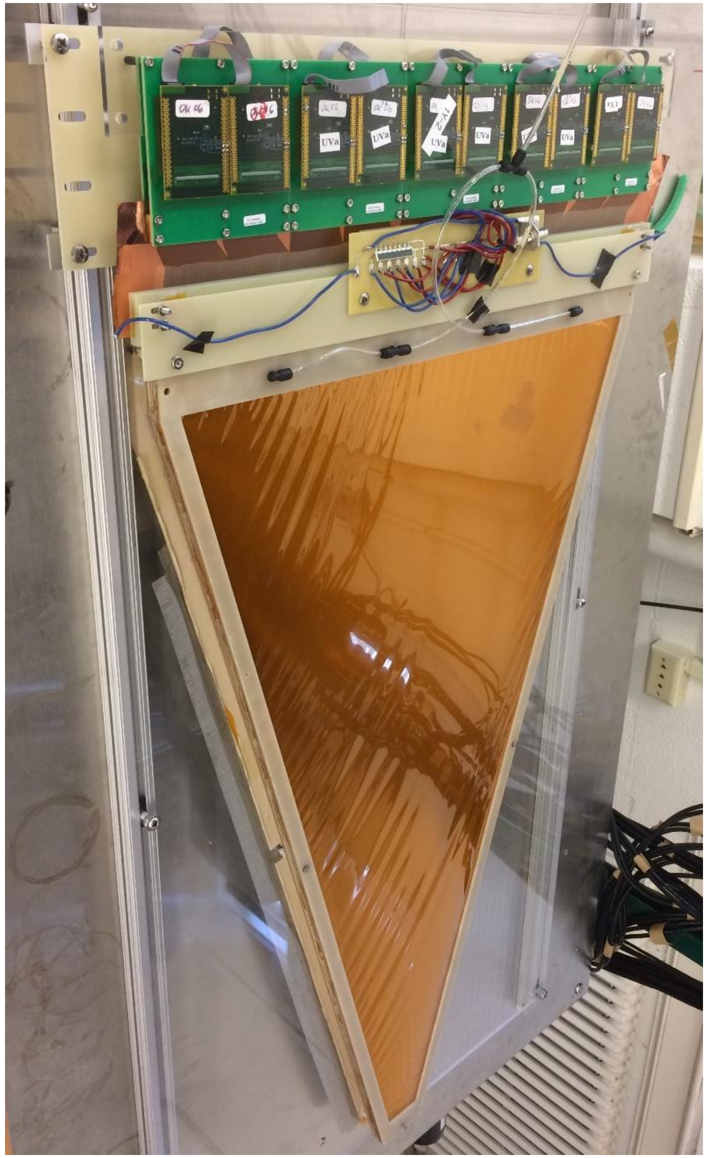



- 2D U-V strips readout a la COMPASS, very good spatial resolution
- No metallized vias to pick up bottom strips signal ⇨Thin Cu layer
- All FE electronics read out all on the outer radius of the chamber

### Cross section of Low Mass EIC-FT GEM

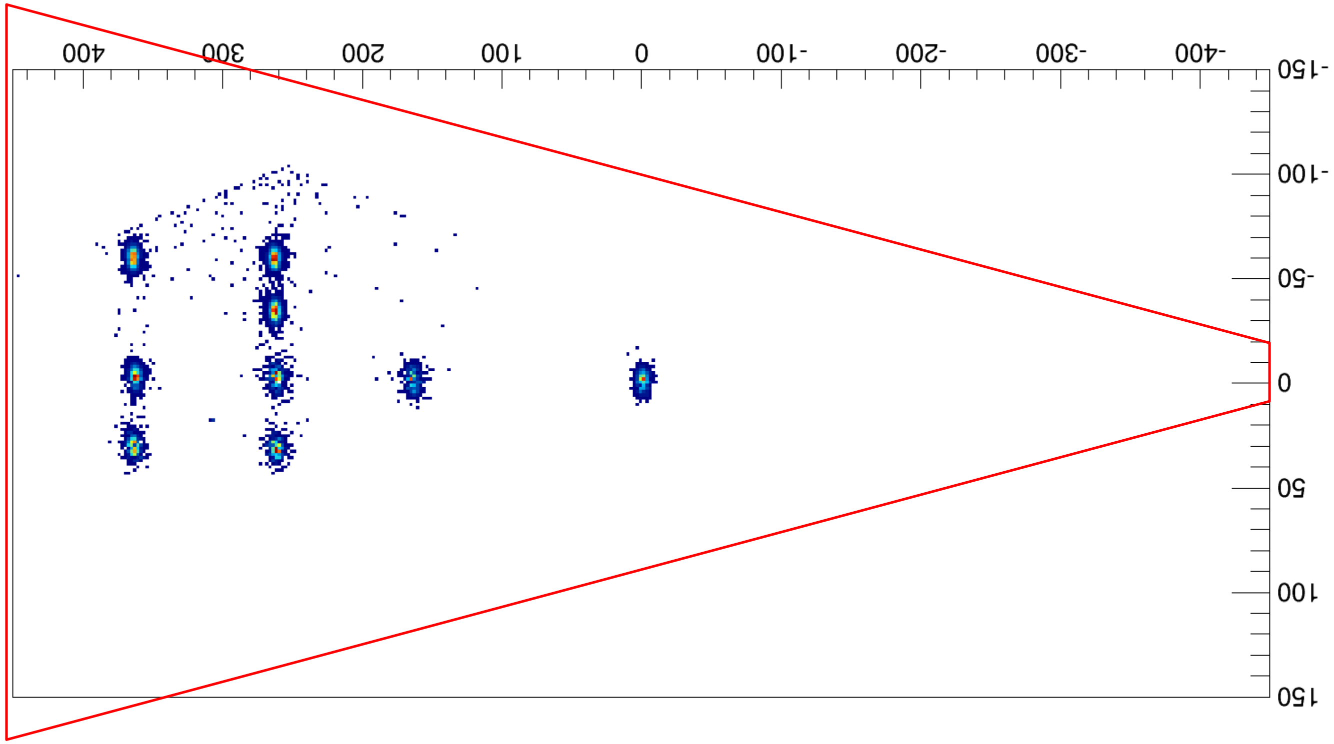


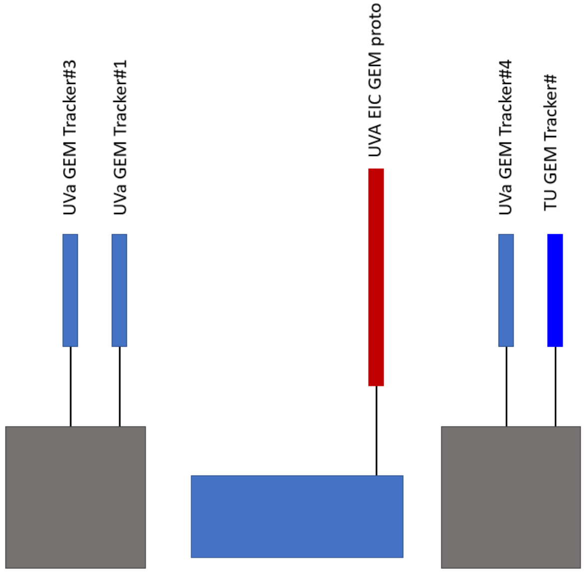

### EIC-FT-GEM Prototype



# Setup 3 @ FTBF MT62.b: Large EIC GEM Protos with U-V Strip R/O

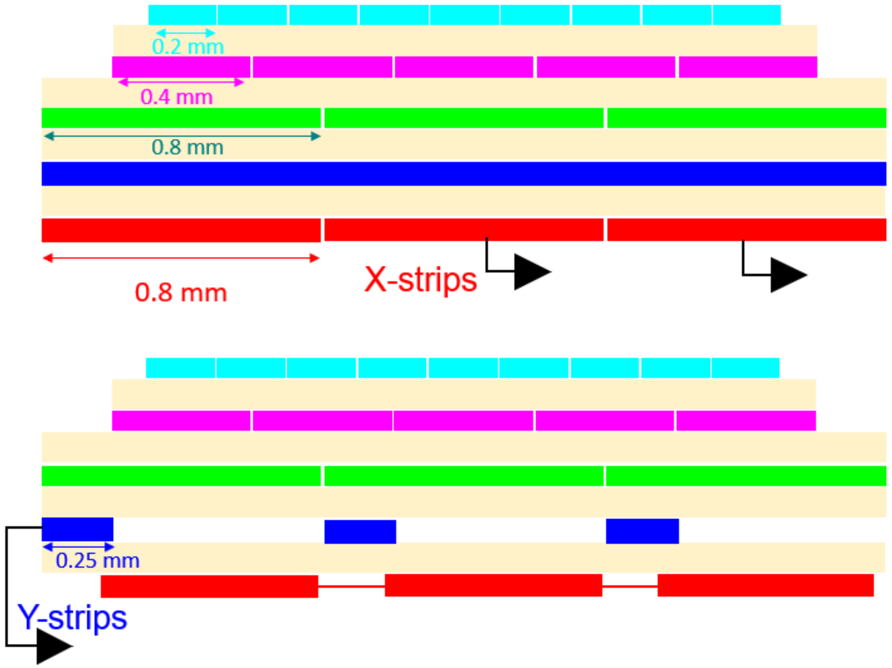
- Good performance overall of the prototype
- Issues with entrance window foil collapsing was solved
- Had same zebra strip for the APV25 signal collection from the detector
  - Improvement to achieve good connection between the zebra strips and the detector strips still needed
  - Impact of on the reconstructed hits could be seen for some runs



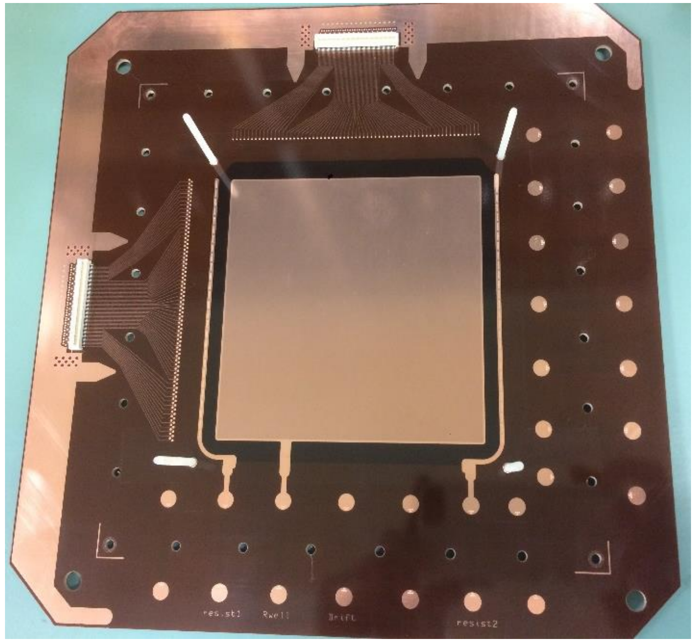



# What was not @ Fermilab: µRWELL with capa-sharing X-Y strips R/O

- Same **800 µm pitch X-Y strip readout as the GEM protos** tested at FNAL beam test
- DLC + 3 pads layers (200 µm, 400 µm and 800 µm pad size) layers on top of the X-Y strip readout layer to help spread the charges
- Additional 200 µm pad layers w.r.t to GEM proto to compensate the smaller cluster size of the induced charges from uRWELL amplification
- X-Y strip design slightly different from the GEM prototype:
  - Move away from pad-like Y-strip to avoid the vias connection
  - Detail of the readout structure on next slide



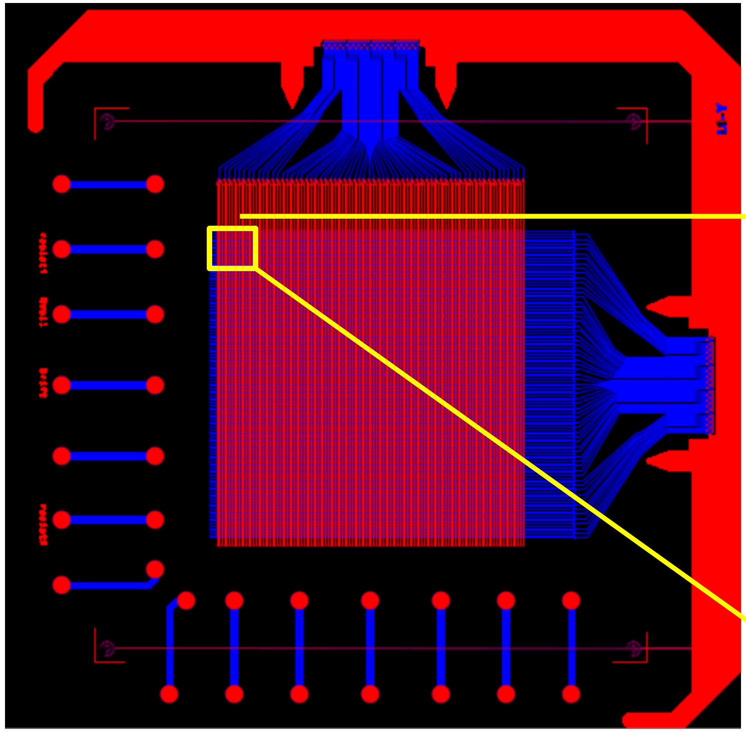

CapaSh µRWELL with X-Y strips

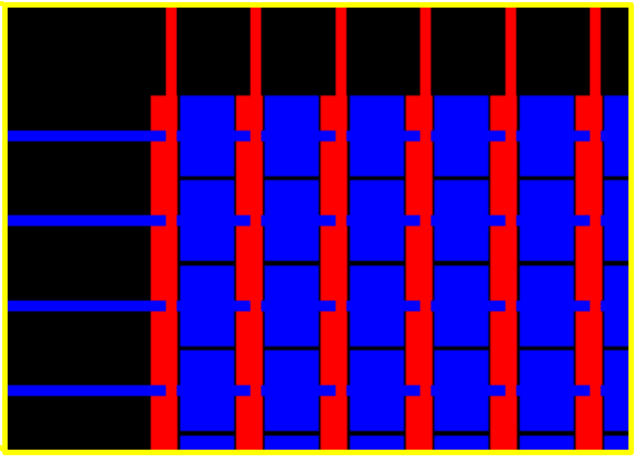


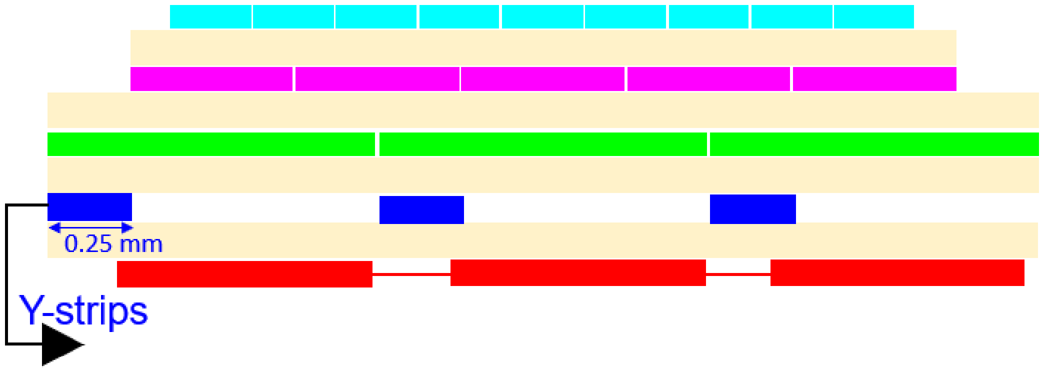
- The parts of prototype was first delivered late directly to Fermilab and assembled in clean room at FNAL but did not work
- Was shipped back to CERN for cleaning and send back to me two weeks ago
- Expect to be tested in beam test at JLab in September 2021

# What was not @ Fermilab: µRWELL with capa-sharing X-Y strips R/O

- X and Y strips on different layers separated by 50 µm Kapton layer
- but unlike “COMPASS” design, Kapton material is not etched out between top and bottom strips
- Signal on top and bottom strip collected through capacitive sharing from the same green pad layer
- But dielectric between green pad layer and bottom strip layer is 100 µm (2 Kapton layers) and 50 µm (1 Kapton layer) for top strip layer
    - Therefore, width of top strip (red) 250 µm smaller than width bottom strip (blue) layer 500 µm to compensate for dielectric thickness
    - The optimal ration will be studied on the next prototype to be procured from CERN
- Strips design optimized to minimize cross talk between ton and bottom strips







# Backup

# COMPASS GEM Trackers (UVa, Florida Tech, Temple U)